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ABSTRACT

The relationship between selective attention and learning is investigated in this paper. It is proposed that two forms of attention exist: (1) inspectional attention, which is a simple matching pocess where perceived stimuli are compared with an internal model of the stimulus for which the individual is searching, and (2) comprehensional attention, which combines the inspectional process with more complex cognitive operations. The stimuli which are searched for and recognized with comprehensional attention must be simultaneously processed with these cognitive operations. It is shown that this added complexity of comprehensional attention has physiological correlates which are qualitatively different from the corresponding concomitants of inspectional attention. The functions of selected attention in learning are also examined. Emphasis is placed on the role of attention in developmental changes that usually occur in the 5-7 year age range. Transposition, reversal shift, and conservation learning processes are also considered. The function of attention in these learning processes is related to blocking effects and surprise. Stimulus novelty and complexity are shown to arouse comprehensional attention, thereby facilitating learning. (Author/WR)

SELECTIVE ATTENTION AND COGNITIVE LEARNING

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WISCONSIN RESEARCH AND DEVELOPMENT
CENTER FOR
COGNITIVE LEARNING

Theoretical Paper No. 45

SELECTIVE ATTENTION AND COGNITIVE LEARNING

by

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Report from the Project on
Children's Learning and Development

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
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Statement of Focus

Individually Guided Education (IGE) is a new comprehensive system of elementary education. The following components of the IGE system are in varying stages of development and implementation: a new organization for instruction and related administrative arrangements; a model of instructional programing for the individual student; and curriculum components in prereading, reading, mathematics, motivation, and environmental education. The development of other curriculum components, of a system for managing instruction by computer, and of instructional strategies is needed to complete the system. Continuing programmatic research is required to provide a sound knowledge base for the components under development and for improved second generation components. Finally, systematic implementation is essential so that the products will function properly in the IGE schools.

The Center plans and carries out the research, development, and implementation components of its IGE program in this sequence: (1) identify the needs and delimit the component problem area; (2) assess the possible constraints—financial resources and availability of staff; (3) formulate general plans and specific procedures for solving the problems; (4) secure and allocate human and material resources to carry out the plans; (5) provide for effective communication among personnel and efficient management of activities and resources; and (6) evaluate the effectiveness of each activity and its contribution to the total program and correct any difficulties through feedback mechanisms and appropriate management techniques.

A self-renewing system of elementary education is projected in each participating elementary school, i.e., one which is less dependent on external sources for direction and is more responsive to the needs of the children attending each particular school. In the IGE schools, Center-developed and other curriculum products compatible with the Center's instructional programing model will lead to higher student achievement and self-direction in learning and in conduct and also to higher morale and job satisfaction among educational personnel. Each developmental product makes its unique contribution to IGE as it is implemented in the schools. The various research components add to the knowledge of Center practitioners, developers, and theorists.

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Abstract

The relationship between selective attention and learning is investigated. It is proposed that two forms of attention exist. "Inspectional" attention is a simple matching process, where perceived stimuli are compared with an internal model of the stimulus for which the individual is searching. "Comprehensional" attention combines the inspectional process with more complex cognitive operations. The stimuli which are searched for and recognized with comprehensional attention must be simultaneously processed with these cognitive operations. It is shown that this added complexity of comprehensional attention has physiological correlates which are qualitatively different from the corresponding concomitants of inspectional attention.

The functions of selective attention in learning are also examined. Emphasis is placed upon the role of attention in developmental changes that usually occur in the 5 to 7 year age range. Transposition, reversal shift, and conservation learning processes are considered. The function of attention in these learning processes is related to "blocking effects" and "surprise." Stimulus novelty and complexity are shown to arouse comprehensional attention, thereby facilitating learning. It is suggested that comprehensional attention may be crucial to cognitive restructuring (learning).

I
Introduction

That attention plays a role in cognitive learning is axiomatic to virtually any model of learning. The extent of this role and its precise nature, however, are currently sources of controversy in experimental psychology. The primary purpose of this paper is to investigate the mechanisms whereby selective attention performs functions integral to the learning process. The phsyiological correlates of attention will be considered. A distinction will be made between attention designed to identify stimuli and attention involved in comprehending a stimulus situation. Next, the functions of attention in cognitive learning will be examined. Here the focus will be upon transposition, reversal shifts, and conservation. Finally, consideration will be given to variables which influence attention. Stimulus novelty and complexity will be examined in terms of their relationship to attention.

II
Inspectional and Comprehensional Attention

A great deal of research has examined physiological correlates of attention, usually autonomic activities such as heart rate and blood pressure. Data suggest that attentional responses can be dichotomized into those correlated with a deceleration of autonomic activity and those associated with autonomic acceleration. It is proposed here that attention associated with autonomic deceleration can be described as a matching operation in which the individual compares external stimuli to an internalized model. Attention associated with autonomic acceleration, however, may involve a more sophisticated level of mental processing. The difference, then, can be understood in terms of the internal processing of the stimuli to which the attention is directed. In more concrete terms, a person watching a crowd of people would show decreased autonomic activity if he were simply trying to find a friend. If the same person were in a foreign country, watching a crowd in an effort to understand what the people were doing and why they were doing it, he would show increased autonomic activity. We shall call the first "inspectional attention" and the second "comprehensional attention." It should be noted that this distinction fits neatly into certain models of concept attainment. For example, in the conceptual learning and development (CLD) model (Klausmeier, Ghatala, & Frayer, in press) the concrete and identity levels require inspectional attention, while all other levels involve comprehensional attention.

Lacey (1967), reviewing a variety of data, concludes:

> Attentive observation of the external environment is productive of cardiac deceleration, cardiac stabilization, and either a blood pressure decrease or a marked diminution of pressure increase. [P. 33]

"Attentive observation of the external environment" is what we have termed inspectional attention. Two experiments are representative of those reported by Lacey in support of his conclusions. In the first study _S_s were required to respond to certain stimuli but not to others. The stimuli were temporally mixed. Monitoring of their simultaneous heart rates revealed that _S_s made more false responses at high heart rates than at low heart rates. This indicates that maximal inspectional attention occurs at low heart rates.

The second experiment relied upon the fact that high alpha levels are indicative of low inspectional attention, whereas low alpha levels indicate high attention. A system was utilized in which a flashing light was automatically turned on when a _S_'s alpha level was high. The light remained on until alpha block was produced and the alpha level became low. This continued throughout the experiment. Simultaneous measurement of heart rate showed that cardiac deceleration occurred during periods of low alpha levels, whereas cardiac acceleration occurred during periods of high alpha levels. Thus, low heart rates were associated with high inspectional attention.

Kahneman, Tursky, Shapiro, and Crider (1969) report an experiment demonstrating what we have called comprehensional attention. _S_s were tested at three levels of difficulty on a paced addition task. Pupil diameter, heart rate, and skin resistance were measured. It was found that autonomic activity increased in all three channels during the input and processing of information, followed by an increace during the report phase. There was also a greater increase in autonomic activity with the more difficult tasks. This shows that the simultaneous attention to and processing of stimuli results in a concomitant increase in autonomic activity. Furthermore, the greater the demands of the internal processing, the greater the autonomic activity. The authors point out that although the energy requirements which mental activity imposes on the organism

are minimal, the associated autonomic activity increases greatly. Recognizing that perceptual capacity varies inversely with the degree of autonomic activity, Kahneman et al. suggest that sympathetic reactions during a mental task may provide a functional desensitization of the organism to environmental stimulation. That is, increased autonomic activity during a mental task may block out environmental stimuli which would otherwise be distracting. Thus, it appears that comprehensional attention is a combination of inspectional attention and the performance of mental tasks that require physiological priority.

Although the bulk of the evidence supports this dichotomization of attention, there are contrary data. However, it is possible that most of these data are special cases within the proposed dichotomy. For example, Clifton and Meyers (1969) report that newborns show cardiac acceleration upon perceiving the same stimuli which produce cardiac deceleration in four-month-old infants. The stimulus situation used should evoke what we have called inspectional attention. The cardiac responses of four-month-old infants fit the foregoing characterization of inspectional attention. However, the newborns displayed cardiac acceleration when deceleration would have been predicted. That this occurred only with newborns allows us to consider it a special case that is not really contrary to the proposed dichotomy. The authors conclude that the different response patterns of the newborns and the four-month-old infants can be explained in terms of the maturation of the orienting response. They suggest that newborns may show cardiac acceleration because they have not yet developed the orienting response. Another explanation is that newborns have not learned to recognize even simple stimuli, so that they cannot simply match new stimuli to internal models using inspectional attention. Rather, they must analyze all stimuli using processes related to comprehensional attention. In either case these data would not violate the basic dichotomy proposed here.

III
The Functions of Attention in Learning

Given this distinction, we can consider the functions of attention in cognitive learning. It will be contended that the fundamental role of attention in learning situations is to select or abstract from the available stimulus display those aspects of the display which are necessary for the appropriate cognitive processing. Hence, we will be dealing with "selective attention." Clearly, selective attention subsumes inspectional attention. It is proposed here, however, that even comprehensional attention is a type of selective attention. Consider once more the example of a person watching a crowd of people. If he is searching for a friend, he must select from the stimulus display that set of stimuii which represents his friend. This is simple inspectional attention in which the major operation is to compare selected stimuli with a known mental model of the desired stimulus. However, if the individual is trying to understand the behavior of the crowd, he must process the stimuli in order to determine whether they allow him to perform the appropriate analysis. It is likely that the individual must not only try various selections of stimuli, but must try various selections of internal processing procedures in an effort to analyze the crowd's behavior.

This integration of stimulus and processing selections is a highly sophisticated operation. As previously suggested, the autonomic acceleration that occurs simultaneously to this complex mental processing may perform the function of minimizing stimulus distractions. The ability to maintain effective selective attention while concentrating one's major effort upon internal processing may be crucial to higher levels of intellectual functioning. Even in the simpler instance of comprehension attention, where stimulus selections are processed by a known procedure such as addition, the concomitant autonomic arousal would result in a more difficult attentional task. That is, attentional abilities must be more highly developed for comprehensional attention, as a compensation for the physiological priority given to the internal processing involved.

Developmental Changes in Attentional Abilities

Kagan and Kogan (1970) present an interesting argument for the importance of selective attention to the learning of transposition, reversal shifts, and conservation. They contend that the development of attentional abilities advances markedly around the age of six years. It is at this general age level that various learning abilities also advance, including transposition, reversal shifts, and conservation. The authors cite several developmental occurrences around the age of six years, suggesting that the central nervous system undergoes crucial maturation at this age level. Among these occurrences are: (1) the amplitude of the visual evoked potential reaches a peak, (2) a sharp increase occurs in the growth of neural tissue, (3) there is a decrease in much of the symptomatology of the autistic child, (4) the possibility exists for safe discontinuance of special diets for children with phenylketonuria, and (5) it becomes safe to discontinue special diets for children suffering convulsive seizures. Kagan and Kogan contend that this evidence of central nervous system maturation at about the age of six years probably underlies the concomitant sharp increase in learning abilities.

A basic contention of the Kagan and Kogan thesis is that attentional abilities increase sharply around the age of six years. The authors point out that the amplitude of the visual evoked potential is correlated with the degree of visual attention shown by a subject. As has already been mentioned, the visual evoked potential reaches a peak at about six years of age. Kagan and Kogan (1970) also report an experiment as evidence of this development of attentional abilities. The Ss

were 200 Guatemalan children between the ages of four and seven none of whom were attending school. Performance assessments were obtained for: (1) an embedded figures test, (2) a matching familiar figures test, (3) a haptic visual matching test, (4) memory for digits, (5) memory for sentences, (6) incidental learning, and (7) vocabulary. Dramatic increases between the ages of four and five and the ages of six and seven were found for the first six tests. Minimal increases were found between the ages of five and six for these same tests. Vocabulary, however, rose linearly from ages four through seven. The authors argue that of the seven tasks, only vocabulary does not require sustained attention. They conclude that the age of six is crucial to the maturation of attention.

One hypothesis of the Kagan and Kogan thesis is that the maturation of the central nervous system may be responsible for the various advances in performance between the ages of six and seven. More importantly, it is suggested that the major direct consequence of this maturation may be an increase in the child's capacity for sustained attention. This would imply that the simultaneous development of new learning abilities, such as transposition, reversal shifts, and conservation, are attributable to the augmented attentional abilities. This hypothesis will be examined, giving consideration to various data purported to demonstrate the role of attention in the development of transposition, reversal shift, and conservation abilities. The Kagan and Kogan data are descriptive and correlational in nature. The data now to be examined involve experimental treatment effects, which supply more direct evidence of the causal relationships which Kagan and Kogan propose.

Transposition learning has been one of the experimental mediums for the demonstration of the role of attention in learning. Caron (1966) found that attentional training enables preverbal children to attain far transposition. Ss in this experiment ranged in age from three years and four months to four years and nine months. The selection of Ss was designed to eliminate the possibility of verbal mediation as a factor underlying the performance of the children. This was accomplished by limiting the sample to those children with I.Q. scores above eighty, but showing a deficiency in the verbal labels relevant to the tasks to be used. The labels tested for were: "medium-sized," "middle-sized," and "medium." The stimuli consisted of nine squares ordered in size (smallest to largest) and grouped by size into three classes (small, medium, and large) with three squares in each group. Two treatment conditions, range and multiple, were included. The task, in all phases of both conditions, was to choose the middle-sized square from whichever set of three squares was presented. In the range condition, Ss were first trained to select the middle-sized square from the group of large squares. They were then trained to transpose to the small squares. Finally they were tested for transposition to middle-sized squares. Ss in the multiple condition were trained on the middle-sized squares first, then the small squares, and finally were tested for transposition to the large squares. Seven correct choices, out of ten trials, was the criterion for successful transposition.

The data revealed that the range condition produced transposition performance superior to that of the multiple condition. It was also found that females surpassed males and that older Ss surpassed younger Ss. The major conclusion of the author is that label deficient Ss can transpose if they are given appropriate training. Even in the multiple condition, 25 out of 79 Ss transposed successfully. (55 out of 83 Ss transposed successfully in the range condition.) This is seen as supportive of attentional, rather than mediational, theory because the Ss lacked the relevant labels and these labels were avoided in all training. Caron's explanation of the superiority of the range condition is that more disparate training sets may better facilitate the abstraction of middle-sizedness. That is, the greater disparity in size of the two training sets may make the dimension of relative size within a set more salient. This would enable the Ss to attend selectively to that dimension.

Many experiments have been conducted using the reversal shift paradigm. Tighe and Tighe (1969) trained Ss, averaging six years and seven months in age, with an attentional procedure expected to facilitate reversal shifts. The stimuli used were blocks varying in height, brightness, and shape. Those Ss receiving pretraining were subdivided into three equal groups for training with one, two, or three variable dimensions. The pretraining procedure required Ss to make same-different judgments on the stimulus objects. Immediately following the pretraining all Ss learned a two-choice discrimination and a discrimination reversal involving the dimensions used in the pretraining. The same number of variable dimensions were used in pretraining and transfer. All dimensions were relevant the same number of times in both the pretraining and the control conditions. The transfer task began with reinforcement of Ss for selecting the correct object. The task was repeated until S made nine out of ten responses correctly.

Then the discrimination reversal was initiated and carried to the same criterion.

The results were based upon the number of errors each S made in reaching the criterion. It was found that pretraining did not affect performance in terms of original learning and that this performance declined as a linear function of the number of irrelevant dimensions. In the reversal shift, perceptually pretrained and control Ss did not differ under the condition of zero dimensions irrelevant. However, as the number of irrelevant dimensions (one or two) increased, the performance of control Ss declined in the same manner as did original learning, while the performance of the pretrained Ss was unaltered.

The authors conclude that the pretraining enabled Ss to perform reversal shifts equally well regardless of the number of irrelevant dimensions. Two explanations were proposed. First, pretraining may have increased the ability of Ss to attend to the separate dimension-reward relations of the tasks. Second, the pretraining may have developed attention to the relevant dimension in the original learning. This would enable the S to react selectively to the relevant dimension in the reversal shift so that he could detect the reversed relation between the values and the reward, regardless of the number of irrelevant features. The inferior performance of the control Ss indicates the tendency for these Ss to attend to only the object-reward relations in the tasks. The authors argue that these Ss respond to the combined cue properties of the objects, rather than attending selectively to each dimension.

A major determinant of an individual's ability to perform reversal shifts is the dominance of the dimension in terms of which that shift must be made. Ss are more successful if the shift is to be made in terms of the S's dominant dimension. Smiley and Weir (1966) demonstrated this with Ss averaging five years and seven months in age. Ss were reinforced for making the correct choice in a discrimination task varying two dimensions, color and form. A pretest was administered to determine each S's dominant dimension. This pretest consisted of training for an initial discrimination, then testing for dominance with a transfer task where either color or form could be the basis of the transfer. For example, if Ss were trained initially to choose blue squares, they might then be tested for transfer with a choice between a blue circle and a red square. Selection of the former would indicate color dominance, whereas selection of the latter would indicate form dominance.

This pretest for color or form dominance was followed by the experimental trials. In the initial learning task, half the Ss were trained on their dominant dimensions, while the other half was trained on their nondominant dimensions. Next, all Ss were trained on a shift task where they could make either a reversal or a nonreversal shift. Finally, Ss were given a test similar to the pretest for dominance, to determine whether the S had made a reversal or a nonreversal shift in the shift task.

It was found that the assignment of Ss to their dominant or nondominant dimension influenced their performance on the final test series. The type of shift was a function of dimensional dominance, in that those Ss trained on their dominant dimension tended to make reversal shifts, while those trained on their nondominant dimension made nonreversal shifts. In addition, the group trained on dominant dimensions reached criterion more quickly and more frequently during the experimental trials.

The role of dimensional dominance in reversal shift tasks might be attributed to attentional behaviors. That is, Ss may attend selectively to dominant dimensions more readily than to nondominant dimensions. Using the reasoning of Tighe and Tighe (1969), as discussed previously, this should facilitate reversal shifts within the dominant dimensions, because Ss would be better able to ignore irrelevant dimensions and to focus upon the reversed relation between the dominant dimension's values and the reward.

Data supporting this reasoning has been reported by Caron (1969). Using a training approach related to the design employed by Tighe and Tighe (1969), Caron demonstrated that sensitization of Ss to their nondominant dimension equalizes dominant and nondominant dimensions as mediums for reversal shifts. Caron used sticks varying in height and brightness (two values each) with children at three years of age. Four groups were included: (1) Ss trained on their dominant dimension, (2) Ss trained on their nondominant dimension, (3) Ss trained on their nondominant dimension following sensitization training, and (4) a control group. The sensitization training was designed to increase the salience of the S's nondominant dimension. This training technique involved teaching the Ss a discrimination task involving both the dominant and nondominant dimensions, but where the relevance of the nondominant dimension was made particularly salient. Hence, Ss receiving sensitization training would be equally likely to attend to their dominant or their nondominant dimensions.

The results showed that Ss trained on their dominant dimension and Ss sensitized to their nondominant dimension were faster in original

learning than the other two groups. Furthermore, both the dominant-trained and nondominant-sensitized groups were more likely to make a reversal shift than a nonreversal shift, whereas the nondominant-trained group was equally likely to make a reversal or a nonreversal shift.

The investigator concludes that the relative inability of very young children to perform reversal shifts may be due to their greater likelihood of mediating irrelevant task dimensions. Caron argues that younger children have less experience with the various available dimensions, and therefore their attention is more likely to be limited to the irrelevant dimension. After experience with the relevant dimension (sensitization), the children attend to it sufficiently to accomplish reversal shifts.

Two comments should be made regarding this experiment. First, its discrimination procedure for training appears to be more powerful than the same-different judgment pretraining (Tighe and Tighe, 1969) in that only the former effected a difference in original learning. It may be that the discrimination procedure was more powerful because it involved comprehensional attention, where the S learned to select the relevant dimension to the exclusion of the irrelevant dimension. The same-different judgment pretraining involves only inspectional attention, in that Ss only needed to recognize perceptual similarity or difference, without performing any further mental processing. Second, Caron's results are unusually impressive in that they were achieved with three-year-old Ss. This is several years before the usual age at which Ss tend toward reversal shifts.

Another category of learning tasks to which the training approach has been applied is that of conservation. Many theorists seriously question whether it is possible to train for conservation at all. Others, such as Gelman (1969), contend not only that conservation can be taught, but that the way in which it can be taught demonstrates the crucial role of selective attention in conservation learning.

Gelman (1969) attempted to train conservation learning with five-year-old Ss who had failed on conservation tests of length, number, mass, and liquid amount. All Ss were trained within two weeks of their initial failure on the tests for conservation. Post-tests were administered on the day after training and again two or three weeks later. Items were added to the post-tests to control for testing effects. In addition, all Ss were trained in terms of length and number, but were tested for length, number, mass, and liquid amount. Three training conditions--one treatment and two control--were employed. The treatment condition consisted of 32 six-trial problems, sixteen with length and sixteen with number. Three stimuli were presented in each trial. The S was asked to point out two stimuli, from the array of three, which were either the same or different in either number or length. In trial one, all cues were both relevant and redundant (i.e., alignment and length for length tasks or alignment, length, and number for number tasks). In trials two through five, alignment and geometric cues were varied independently of length and/or number cues. In trial six irrelevant cues were eliminated. One of the control conditions consisted of training identical to that described above, except that no feedback was provided to the S as to the accuracy of his responses. The other control condition involved training that was unrelated to conservation.

The post-tests after initial training for conservation showed nearly perfect specific transfer (length and number) and about sixty percent nonspecific transfer (mass and liquid amount). Ss with no feedback attained 27 percent specific transfer and virtually no nonspecific transfer. In addition, Ss trained with feedback offered better explanations for their correct responses.

Gelman concludes that the short-term training could only have been effective if the Ss were not learning from a total absence of conservation. It is possible that conservation responses are within a child's repertoire, but are dominated by strategies under the control of irrelevant stimuli. This interpretation attributes the final attainment of conservation to selective attention where the child focuses upon the relevant stimuli alone. It should be noted that this would be comprehensional attention, in that the child must employ complex processing to determine which stimuli warrant his selective attention. That is, the nonconserving response results from selective attention to irrelevant stimuli. The child must discover that he is attending to the wrong set of stimuli and thereafter resample the stimulus array in an effort to identify the relevant stimuli.

The role of comprehensional attention in the attainment of conservation can be understood in terms of two concepts in learning theory. Trabasso and Bower (1968) discuss a "blocking" effect, in which a previously learned cue blocks the learning of a redundant, relevant cue added later. Although the authors do not report the demonstration of this concept with conservation, generality is established with both discrimination and paired associate

learning. Trabasso and Bower suggest that blocking can be explained as the failure of Ss to resample when they are correct initially.

This concept would seem to apply well to conservation. For example, the failure to conserve number may be attributed to attention to the relative lengths of rows of dots rather than to the number of dots in each row. In many instances, attention to length will yield the correct response in a situation requiring conservation of number. That is, in naturalistic situations the longer row is usually also the row with more dots. Length and number would therefore be redundant relevant cues. The young child may not be able to count and may have difficulty comparing rows dot for dot. He would therefore rely upon the length dimension as his cue for number. Most of the time, the child would be correct, even though he would not be using the right dimension as his cue. As Trabasso and Bower would explain, length would become a blocking cue because its initial effectiveness prevents the child from resampling in the face of subsequent failure. By the same fashion, alignment can become a blocking cue for conservation of length, while height (or width) can create a blocking effect for conservation of liquid amount.

A second concept pertinent to the role of attention in conservation is Charlesworth's (1969) notion of "surprise." Charlesworth's account of the function of surprise in cognitive learning could explain how the blocking effect is overcome, thereby freeing the child to restructure his cognitive approach to conservation tasks. Surprise is said to be the result of misexpected events, as opposed to unexpected events. The latter may result in a startle reaction or the perception of novelty. No cognitive restructuring results from startle, while only slight restructuring comes from novelty. Surprise is caused by misexpectation, in that the stimulus event is recognized as counter to previous expectations. This compels the individual to seek new expectations. Hence, those Ss in the Gelman (1969) experiment who received training without feedback did not restructure their cognition of conservation because they did not recognize that their expectations were not fulfilled. In the Gelman procedure, feedback serves the crucial function of ensuring the recognition of misexpectations. As Charlesworth (1969) explains, surprise arouses attention and the attention enables the child to realize new dimensions essential to the attainment of conservation. This attention must be based upon the recognition of misexpectation. Comprehensional attention is therefore required, because inspectional attention does not involve expectations at all. Rather, it consists of an observational identification process devoid of anticipation. The role of comprehensional attention in the learning of conservation, after surprise has occurred, is to select new dimensions, processing each in a variety of ways, until the appropriate combination of selective attention and mental processing is found.

The Influence of Stimulus Variables on Attention

Having considered the influence of selective attention on learning, we will now examine the influence of the material to be learned, that is, stimulus variables, on attention. The role of stimulus variables in attentional processes is often examined in terms of cue salience. This involves the properties of a stimulus which attract the S's attention. The present discussion will consider stimulus novelty and complexity as crucial sources of stimulus salience, not only because novelty and complexity tend to attract attention, but because attention generated by either of these factors is relatively likely to result in new learning. Consider our discussion of Charlesworth's (1969) analysis of the relationships between startle, novelty, surprise, and cognitive restructuring. Whereas startle, novelty, and surprise all arouse attention, only novelty and surprise are likely to lead to cognitive restructuring. Complexity may be thought of as contributing to surprise, in that surprise involves a misunderstanding (misexpectation) of events which could only occur if those events are complex relative to the individual's existing cognition. Hence, Charlesworth's analysis would suggest that attention aroused by stimulus novelty or complexity is relatively conducive to new learning (cognitive restructuring).

Cantor (1963) has defined novelty and complexity. Novelty is:

> the presence in a stimulus of some property never perceived previously by the organism ("absolute" novelty) or the presence of familiar elements or qualities in a combination or pattern which is new in the organism's experience ("relative" novelty). [P. 4]

Cantor defines complexity as:

> the amount of variety or diversity in a stimulus pattern. Degree of complexity

is considered by Berlyne to be positively related to the number of distinguishable elements in a stimulus complex and to the extent of dissimilarity between elements; complexity varies inversely with the degree to which several elements in a complex are responded to as a unit. [P. 4]

It is clear that these definitions would allow both novelty and complexity to be part of cognitive restructuring, as suggested by Charlesworth (1969). In fact, Cantor contends that "surprisingness" is "highly related" to novelty and complexity. Cantor's emphasis upon the perception of new combinations or patterns of familiar elements, which he calls "relative" novelty, underscores the relationship between novelty and cognitive restructuring. Similarly, the suggested inverse relationship between complexity and the degree to which a complex is responded to as a unit reveals one way in which complexity could lead to cognitive restructuring. That is, in the same sense that cognition could be restructured by recognition of novel combinations or patterns of familiar elements, cognition might also be restructured by differential responses to a stimulus array that was previously treated as a unit. Clearly then, stimulus novelty and complexity should be related to new learning (cognitive restructuring). It remains to be demonstrated, however, that these stimulus properties utilize the arousal of attention in the attainment of new learning.

Reviewing various studies, Cantor (1963) concluded that a definite attentional preference for novel, rather than familiar, stimuli has been demonstrated. Hartup and Yonas (1971) reach the same conclusion based on their own review of the literature. Available data also suggest that the particular relationship between novelty and attention is one where new learning is involved. Hartup and Yonas report that most of the data (though not all) show autonomic deceleration upon attention to familiar stimuli and autonomic acceleration with attention to novel stimuli. This suggests that familiar stimuli arouse inspectional attention, while novel stimuli arouse comprehensional attention. The relationship between comprehensional attention and intense mental processing suggests that novel stimuli are more likely to instigate new learning than are familiar stimuli. This conclusion is supported by Maccoby's (1967) demonstration that familiarity with a stimulus array facilitates selective attention to the elements of that array. This suggests that more intense mental processing would, indeed, be required for selective attention to a novel stimulus array. Although it may be easier to attend selectively to a familiar array, there is probably more to be learned through attention to a novel array.

A similar relationship can be shown among attention, complexity, and learning. Cantor, Cantor, and Ditrichs (1963) demonstrated a positive association between attention and stimulus complexity, using time spent viewing a stimulus as the criterion of attention. However, Cantor (1963) concludes from his review of the literature that the data do not show a clear relationship between attention and complexity. Although Hartup and Yonas (1961) find the same ambivalence in the literature, they consider the possibility of reconciling the data with the notion of intermediate or relative complexity. That is, there is some support for the proposition that people attend more to stimuli of intermediate complexity, the precise level of complexity preferred being determined by the individual's relative ability to comprehend a stimulus configuration. It is also suggested that attending time may be a function of the time required to process the stimulus. Perhaps attention increases as a function of processing time, which would be a function of complexity, up to a tolerance level, beyond which the S becomes overwhelmed. At that point the S may not attempt to fully comprehend the stimulus, so that, beyond this tolerance level, attention time and complexity would be inversely related.

The preceding analysis suggests that attention and complexity are positively associated as long as the individual is able to successfully process the complex stimulus. The conclusion that attention and complexity are related through the occurrence of learning, is supported by the data of Trabasso and Bower (1968), which show that an increase in the number of irrelevant cues results in slower discrimination learning. That is, a greater attending time is required to learn a discrimination problem involving stimuli complicated by irrelevant cues. Hence, stimulus complexity appears to arouse comprehensional attention in that attention to a complex stimulus invokes a relatively intense cognitive processing effort. It may be concluded that both novelty and complexity result in new learning (cognitive restructuring) insofar as they are able to arouse comprehensional attention.

IV
Conclusion

It is clear that attentional processes are crucial to much of the learning that occurs in childhood. The physiological correlates of selective attention suggest a dichotomy which has been found useful in the analysis of various learning studies. Inspectional attention is accompanied by autonomic deceleration which allows maximal concentration of selective attention upon the available stimuli. Comprehensional attention is associated with autonomic acceleration which enables the S to avoid stimulus distractions by shutting them out with autonomic activity. This assigns a priority to internal processing of the stimuli perceived with comprehensional attention. It was suggested that comprehensional attention may require more sophisticated abilities than would inspectional attention. As one might expect, the analyses of learning processes indicate that comprehensional attention is more important to cognitive restructuring than is inspectional attention.

Examining the role of attention in learning, it was noted that maturational evidence suggests that the sharp rise in learning abilities at the age of six years may be attributed to the development of attentional abilities. A study of transposition training was shown to exclude mediational theory as an alternative to attentional explanations of the effect of the training. Studies of reversal shift learning show that attentional training procedures may also be used to teach young Ss to perform reversal shifts. It was found that the most effective training procedure incorporated comprehensional attention rather than inspectional attention. Attentional training procedures may also be employed to teach conservation, with both stability and generalizability. The training procedure examined was found to invoke comprehensional attention as a means of enabling children to separate relevant from irrelevant dimensions. It was suggested that the failure to conserve may be attributed to a "blocking effect," in which the child's selective attention to an irrelevant dimension blocks the relevant dimension from his purview. "Surprise," or the misexpectation of events, was shown to be a helpful concept in understanding the attainment of conservation. It was suggested that comprehensional attention is necessary to overcome the blocking effect and thereafter achieve conservation.

The examination of stimulus variables which influence selective attention was focused upon novelty and stimulus complexity. It was proposed that both stimulus novelty and stimulus complexity arouse comprehensional attention. The arousal of comprehensional attention may be the mechanism through which these stimulus variables facilitate cognitive restructuring.

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